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ABSTRACT

Slaney, P.A., M.L. Rosenau, A.D. Martin, G.D. Taylor, G.E. Reid, D.H.G. Ableson. Yield, Effort and Catch Characteristics of Resident Trout and Char Fisheries on Streams. 1984. Fisheries Technical Circular No. 65. 10 p.

More intensive management of resident salmonid fisheries on > 300 streams in British Columbia requires estimates of biological capability for the more important and accessible streams. Capability for resident trout and char can be defined as standing crop (kg/ha, late summer) under moderate fishing pressure, or sustained standing crop, which can be estimated from capability models. Based on a limited sample of intensively managed stream fisheries in the United States, annual sustained yield of trout and char (kg/ha) was correlated with standing crop and was equivalent to an average of 41% of the standing crop of unstocked streams. Angling effort varied considerably for accessible stream fisheries for trout and char; stream size, productivity and stocking all appeared to affect angler days per hectare. Total catch (kg/ha of harvested plus released trout and char) was similar to yield or harvest on streams with liberal regulations. Under special (or limited kill) regulations, yield was substantially reduced, but total catch typically doubled.

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This review of habitat capability was requested and encouraged by A. F. Tautz (Manager, Research and Development) and D. W. Narver (Director of Fisheries Branch). Review of the manuscript by R. Ptolemy, R. Griffiths and particularly E.A. Parkinson was appreciated. I. Warner typed the report.

INTRODUCTION

Stream fisheries for resident salmonids account for 20% of freshwater angling effort during 1978-79 in British Columbia (Warner 1980 M.S., B. Ford, pers. comm., re-analysis of Warner 1980). There are at least 300 mainstem streams, or about 20,000 km, that can be identified as fair to excellent in their potential for angling of non-anadromous salmonids (Slaney and Rosenau 1982 M.S.). The importance of stream angling is clearly demonstrated by angler surveys which indicate strong preferences for riverine fishing over lake fishing for trout (e.g. Idaho; Gordon, Chapman and Bjornn 1969, Mallet 1980).

Estimates of the salmonid fisheries capability of lakes and streams in British Columbia are important for fisheries management including planning of the fisheries program. Although stream fisheries for resident salmonids account for considerable angling effort in the province, in contrast to lakes there is no published methodology to predict yield capability for trout and char. An empirical model was developed in Wyoming by Binns and Eiserman (1979) to predict late summer standing crop of trout and char in streams. Provided standing crop and yield are related, yield can be calculated from the former. Similarly, total catch (i.e. kept plus released fish) could be estimated from these yield calculations if assumptions are made about hooking mortality, or preferably if there are published comparisons of yield and catch under both liberal and restrictive regulations on typical streams.

The purpose of this report is to describe how standing crop models for stream salmonids could be utilized to predict potential yield and catch which can be, in turn, used to assemble a capability inventory for the more important resident salmonid streams in British Columbia.

PREFERRED UNITS OF MEASUREMENT FOR CAPABILITY ANALYSIS

Catch and effort statistics for stream capabilities can be expressed either numerically or by weight, per unit area or length. Weight is preferable because it provides a standard measure of capability which is, to some extent, independent of fish size. Both units of length and area are useful because the former is rapidly measured from maps and the latter because it compensates for varying width. Yield or standing crop of salmonids from a narrow stream is less per km than per hectare, but is vice versa from a wide stream (Table 1; from Appendix 1 and 2). Most reported standing crop and yield data for streams are expressed by area in hectares. Therefore, weight or biomass per unit area (i.e. kg/ha) is the preferred unit for yield, catch and standing crop.

Table 1. Comparison of mean standing crops (late summer) of resident salmonids in productive streams (excluding whitefish) expressed per unit length and unit area for three stream size categories.

	Standing Crop kg/ha	Standing Crop kg/km
Small streams (width < 10 m; n = 7)	144	63
Medium streams (width ca. 20 m; n = 3)	73	106
Large streams (60 - 100 m; n = 3)[1]	49	351

[1]includes 2 reaches of Madison River

PREDICTION OF POTENTIAL YIELD

It is well documented from studies of lake fisheries that yield increases as a function of lake productivity which can be predicted by use of various physical and chemical parameters including TDS, mean depth and shoal area (e.g. Ryder et al. 1974). Streams also vary greatly in biological productivity and thereby in potential yield of salmonids (Cooper and Sherer 1967; Binns and Eiserman 1979).

The Binns and Eiserman model does not predict yield, but rather late summer standing crop in kg/ha (age 1+ and older trout and char). It requires measurements of nine parameters and conversion of each into a five point index. For streams where data on these variables is unavailable an alternative to the Wyoming HQI model is a simplified habitat capability model (HCM) that sacrifices accuracy for expediency. Data from 24 streams, primarily from Wyoming, were analyzed by multiple regression techniques. This approach resulted in a preliminary model that predicts standing crop by incorporating two variables; salmonid cover and stream nitrate nitrogen, measured in August to September. Late summer to fall standing crop in kg/ha of trout and char (> age 1+) was predicted with 92% of the variance accounted for by the regression equation, although with a high standard error of + 47 kg/ha (Rosenau and Slaney 1982 M.S.). The HQI model is described in a manual (Binns 1982) and the equation

for the simplified capability model (HCM) is (each measured in late summer to early autumn; intercept forced through zero):

$$SC = 190\ (C) + 13{,}900\ (NO_3N)^2$$

where SC = standing crop of trout and char in kg/ha
NO_3N = nitrate nitrogen in mg/l
C = salmonid cover as a proportion of 'wetted area'

Standing crop in both these models is equivalent to that remaining after moderate fishing pressure; i.e. "sustained standing crop".

The latter preliminary model may not be applicable to streams with physical and chemical values that exceed the limits of data used in the regression analysis. These include: width < 3 m or > 99 m, NO_3N < 0.01 mg/l or > 0.15, and cover < 0.11 or > 0.78. Improvements in accuracy could be obtained by collection of additional standing crop data. Eventually, a standing crop model should be developed from data collected from a set of various types of streams in British Columbia.

Adjustments in these models may also be required to correct for atypical conditions including migratory lake stocks of salmonids. Contributions to standing crop from migrant lake salmonids moderately influence approximately 25% of stream fisheries in British Columbia (Slaney and Rosenau 1982 M.S.). Also, high sediment loads, extreme temperatures and extremely unstable flows are not accounted for except in the HQI model.

Few studies of stream fisheries in North America have examined both standing crop and yield, but data were available for eight streams, particularly from Wisconsin where streams are more intensively managed than elsewhere (Appendix 1). Streams were separated into "stocked" (juveniles) and "unstocked" (natural reproduction required) and yield plotted against fall standing crop (unstocked streams, r = .74, n = 7). Because exploitation rates were moderate and sustained (33% of mature fish or 20% of fish >15 cm; April numbers), it was assumed these fisheries were managed near maximum sustained yield (MSY; Ricker 1958). Yield from unstocked streams ranged from 16 kg/ha to 77 kg/ha.

Yield from stocked streams was approx. twice that of unstocked streams (Table 2). On average, annual yield or harvested biomass was 41% and 100% of standing crop in "unstocked' and "stocked" streams, respectively. (One stocked stream, the Green River in Wyoming, was excluded because the exploitation rate was atypically low; i.e. 12% of rainbow trout.) However, some caution is recommended for application of these percentages to stream trout and char fisheries in British Columbia. Our streams are generally less productive resulting in

lower survivals and fecundities. A more realistic yield target in kg is 25% of standing crop capability.

Table 2. Mean harvested biomass or yield per hectare per year as a proportion of the standing crop[1] (late summer to fall standing crop, age 1+ and older trout plus char).

	Stocked Streams (n = 2)	Unstocked streams (n = 7)
Yield/Standing crop	$\frac{1.0}{.94}$ to 1.14)	(range $\frac{0.41}{.23}$ to .56)

In British Columbia there are approximately 300 mainstem streams totalling greater than 17,000 km in length that provide existing fisheries for resident trout and char (Table 3). This does not include the numerous tributaries and smaller streams that also are inhabited by fishable salmonids. Geographic regions with the greatest percentage of stream length are Omineca-Peace (47%), Kootenays (16%) and Thompson-Okanagan (14%), the latter having the most accessible stream fisheries. Physical and chemical variables can be measured by reach for each of the more accessible streams, and the mean standing crop estimated from model calculations. Potential yield can be estimated from the yield/standing crop ratio (Table 2). Surveys of standing crop at key streams should be utilized to indicate where existing regulations could be ineffective (Slaney et al. 1984 M.S.). Where the measured standing crop is substantially less than the model predictions either regulations are too liberal or there are significant sources of mortality other than fishing.

ANGLING EFFORT

Several studies have been conducted of angler effort expended on resident trout and char fisheries on streams, particularly in Wisconsin and Idaho (Appendix 1). On average, small productive streams (< 10 m wide) support approximately twice the number of angler days per hectare (400 days) as productive streams of medium size (200 days) (Appendix 1). Annual stocking of juveniles (i.e. 10 to 15 g fall fingerlings or yearlings) to maintain a moderate harvest success (e.g. 1 to 2 fish/day) maximizes effort, approaching 1000 days/km or 800 days/ha in highly productive streams, 12 to 13 m in width (Appendix 1). In contrast, an unstocked reach of an unproductive stream (20 m wide), the Cache la Poudre River in Colorado, supported an average of 34 days/ha or 67 days/km (Appendix 1, 2; Klein 1974). Average effort on five moderately productive rivers in Idaho was 300 days/km, and 232 days/km (trout and char) on the Elk River in B.C.

Table 3. Numbers and total lengths[1] of streams by region supporting stream fisheries for resident salmonids. (Very small streams and tributaries of mainstems are excluded.)

	MANAGEMENT AREA								
	Van. Is.	Southern Mainland	Thompson	Kootenays	Cariboo	Skeena	Omineca-Peace	Okanagan	Total
Number of Streams	25	20	28	68 (+ 5)[2]	29	38	77	20	305
Total Length (km)	371	419	1,354	2,703	1,552	1,587	8,094	1,025	17,105
Mean Length (km)	15	21	48	39	54	42	104	51	56

[1]Lengths are minimums because these were measured from large scale maps

[2]Whitefish only

Large rivers (e.g. 100 m wide) may not generate high levels of effort per ha because stream anglers prefer intermediate or small streams that are more accessible and easier to fish (Wiley and Dufek 1980). For example, the Green River in Wyoming, a productive stream similar in size to the Thompson River in British Columbia, supported only 60 days/ha (600 days/km) despite extensive stocking with juvenile rainbow trout (Appendix 1).

Potential effort is probably also a function of several other variables including accessibility, number of fishing sites, CPUE and crowding, if harvest is regulated. However, key variables on accessible streams appear to be size of stream, productivity and stocking.

TOTAL CATCH CAPABILITY

Annual total catch can be defined as the total biomass of trout and char that are harvested plus released. Potential catch should also be a function of standing crop, but at some level greater than potential yield, depending on how a fishery is regulated. Catch is only slightly more than yield in fisheries that are liberally regulated (Appendix 1). However, when well designed "special regulations" are imposed to reduce yield well below MSY, most fish are released and total catch can be increased substantially, typically by 100% (Appendix 1, Slaney et al. 1984 M.S.).

Several studies have documented both an improved catch and a higher quality fishery. Catch was approximately doubled at a productive Wisconsin stream (Race Branch River) to about 230 kg/ha/yr when anglers were restricted to one fish per day, fly only, and a minimum size of 33 cm. Effort was maintained at 850 days/ha, the same as at unrestricted streams, and fish greater than 33 cm increased by 12% in the catch (Hunt 1981). Similar results occurred at another productive but larger stream, the S. Fork Boise River in Idaho, where possession was restricted to three fish of a minimum length of 30 cm. Compared to an earlier catchable plus wild trout fishery, total catch of trout increased by 80% (Moore, Cadwallader and Mate 1979 M.S.). Effort declined by 29%, but this can be attributed to cessation of stocking of catchables. Total catch of wild rainbow trout alone increased approximately 400% to 183 kg/ha or 459 kg/km, with an exceptional catch success of four per day, about three times that of fisheries without special regulations. Harvest of trophy trout (> 41 cm) also increased from 5% to 26% after two years, although as expected, total yield of trout > 30 cm was low, 11 kg/ha (Appendix 1). A 64% increase in catch was evident at the Coeur d'Alene River after similar special regulations. However, although age 1+ and older trout increased 26% in the river, catch of fish > 33 cm did not change, mainly as a result of non-compliance (Lewynsky M.S. 1982). Lewynsky and Bjornn (1982) concluded that special regulations had clearly "arrested" the

apparent decline of west slope cutthroat trout in the Coeur d'Alene River. Where stocks of trout have been depressed by over-exploitation by anglers, increases are typically larger; 5-fold in catch and 10-fold in numbers as a result of a catch and release regulation (Nehring 1983, Nehring and Anderson 1983). Accordingly, catch rates increase markedly (e.g. Anderson and Nehring 1984).

Special regulations that are "too liberal", however, may result in only a small increase in total catch. At the Cache La Poudre River in Colorado a size limit of 30 cm, no bait, a 6 to 10 possession limit and the cessation of stocking catchables were imposed on a wild trout fishery. Only a 20% increase in catch of wild trout was recorded, probably because fish rarely grew to 30 cm in this relatively unproductive river. There was also little change in effort. In the stream, fish > 30 cm did not increase significantly, but 25 cm rainbow trout became more abundant (Klein 1974). If size and possession had been set lower (e.g. 25 cm, 2 fish), thus reflecting the low productivity of the stream, angler use and total catch would probably have improved more without risking over-exploitation.

There is also limited evidence that special regulations can fail owing to high over-winter mortality (e.g. Gallatin River; Wells 1983). Further research is required, particularly for streams with severe winter conditions or low productivity.

SUMMARY

Effective management, including planning, of resident trout and char fisheries on approx 300 streams in British Columbia, requires some inventory of biological capability, particularly for the more important and relatively accessible rivers and creeks. Harvest can be regulated according to both stream productivity and accessibility.

1. Capability of streams for resident trout and char can be defined in terms of standing crop capability under moderate fishing pressure (or sustained standing crop). Potential standing crop can be estimated from capability models.

2. The preferred model for prediction of standing crop capability in British Columbia is the Habitat Quality Index (HQI) which is available in a detailed manual (Binns 1982), although further testing and modification is required. A simpler (but less accurate) 2 variable model, (HCM; Rosenau and Slaney M.S. 1983) can be utilized for a 'first estimate' where data is inadequate for the nine parameters used in the HQI.

3. Although data was only available for a limited sample of stream fisheries, annual yield or harvested biomass was 41% of standing crop in streams reliant on natural recruitment,

and in contrast 100% of standing crop in streams stocked annually with juveniles. Owing to the lower productivity of most rivers in British Columbia, a yield of 25% of predicted standing crop is considered as a more realistic target for unstocked resident trout and char fisheries (assumes populations are near carrying capacity).

4. Angling effort varies considerably in accessible stream fisheries that are managed; size, productivity and stocking apparently affect effort level. Small productive streams supported twice the angler days (400 days/ha) of medium size streams (20 m wide; 200 days/ha). Stocked streams, of similar size, supported about twice this effort. An unproductive (TDS < 50), unstocked stream supported the least angler days; 34 days/ha or 67 days/km.

5. Total catch capability (harvested plus released biomass) is similar to harvest or yield on streams with unrestricted regulations. However, well designed "special regulations" (limited kill; < 3 quota, size limit and a bait ban in summer), which reduced yield well below maximum sustainable, typically doubles total catch without a significant loss of effort. Although non-compliance can reduce improvements in fish size, excessive exploitation is arrested.

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Appendix 1. Effort, catch, yield, and standing crop statistics for resident salmonid streams in North America, by area (hectares) (excluding whitefish) (standing crop = age 1+ and older, mainly fall estimates).

Stream	m Width	Loc.	Days/ha Effort	kg/ha Catch	kg/ha Yield	kg/ha St. Crop	cm Size Reg.	TDS	Stocked	Species	Source
S.F. Boise[2]	∿25	Id.	189	183	11	-	30	-	Nil	Rbt	Moore *et al.* 1979
C.L. Poudre[2]	20	Col.	34	43	6	72	30	44	Nil	*Rbt*, Brn	Klein 1974
C.L. Poudre[3]	20	Col	29	35	26	(Spring) 53	15?	44	Catchables excluded	" "	" "
Oldman[1]	11	Alta.	182	∿ 47	45	-	Nil	262	Nil	*Cut*, DV	Radford 1975
Willow	13	Wisc.	672	∿100	79	69	15	258	@ 15 g	*Brn*, Rbt	Hunt 1981
Race	12	"	878	∿120	90	96	15	274	@ 15 g	" "	" "
Race[2]	12	"	836	∿230	5	145	33	274	@ 15 g	" "	" "
Green	99	Wyo.	59		7.3	55	15?	300	@ 10 g	*Rbt*, Brn	Wiley & Dufek 1980
Dutch[1]	8	Alta.	339	∿ 45	43		Nil	233	Nil	*Cut*, DV	Radford 1975
L. Plover	4	Wisc.	559		50	93	15	234	Nil	Brk	Hunt 1979
Lunch	4	"				152	15			Brn	Hunt 1979
Spring	3	"				176	15			Brk	Hunt 1979
Wedde	4	"	422		77	183	15	193	Nil	*Brn*, Brk	Avery & Hunt 1981
Radley	5	"	327		44	149	15	204	Nil	" "	" " "
Mecan	7	"	383		41	83	15	223	Nil	" "	" " "
Emmons	6	"	340		39	169	15	220	Nil	" "	" " "

[1]Rotational openings (annual).
[2]Special regulations.
[3]Section (1) 16 kg/ha yield, 44 kg/ha spring standing crop; Section (2) 35 kg/ha yield, 62 kg/ha S.C.
(Note: spring standing crops are slightly less than fall standing crops because growth compensates for moderate fishing mortality.)

Appendix 2. Effort, catch, yield and standing crop statistics for resident salmonid streams in North America, by length (km) (excluding whitefish) (standing crop = age 1+ and older, mainly fall estimates).

Stream	m Width	Loc.	Days/km Effort	kg/km Catch	kg/km Yield	kg/km St. Crop	cm Size Reg.	TDS	Stocked	Species	Source
S.F. Boise[2]	∿25	Id.	473	459	27	-	30	-	Nil	Rbt	Moore *et al.* 1979
C.L. Poudre[2]	20	Col.	67	73	11	132	30	44	Nil	*Rbt*, Brn	Klein 1974
C.L. Poudre	20	Col.	56	69	51	106	15?	44	Catchables excluded	" "	" "
Oldman[1]	11	Alta.	200	∿ 88	86	-	Nil	262	Nil	*Cut*, DV	Radford 1975
Willow	13	Wisc.	898		106	91	15	258	@ 15 g	*Brn*, Rbt	Hunt 1981
Race	12	"	1054		108	115	15	274	@ 15 g	" "	" "
Race	12	"	1004		6	175	33	274	@ 15 g	" "	" "
Green	99	Wyo.	596		73	552	15?	300	@ 15 g	*Rbt*, Brn	Wiley & Dufek 1980
Dutch[1]	8	Alta.	271	∿ 37	35		Nil	233	Nil	*Cut*, DV	Radford 1975
L. Plover	4	Wisc.	217		19	36	15	234	Nil	Brk	Hunt 1979
Lunch	4	"				56	15		-	Brn	Hunt 1979
Spring	3	"				53	15		-	Brk	Hunt 1979
Wedde	4	"	156		29	70	15	193	Nil	Brn, Brk	Avery & Hunt 1981
Radley	5	"	172		23	76	15	204	Nil	" "	" " "
Mecan	7	"	180		28	55	15	223	Nil	" "	" " "
Emmons	6	"	197		23	98	15	220	Nil	" "	" " "
Lochsa		Id.	230 }								Lindland & Pettit 1981 MS
Henrys F.		"	339 }	medium to							Rohner 1981 MS
Teton		"	162 }	large streams							Jeppson 1982 MS
S.F. Snake		"	293 }								Moore 1980
Elk[3] (100 km)		B.C.	232								Martin 1983

[1]Rotational openings (annual)
[2]Special regulations
[3]Plus 209 days/km on whitefish

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